CHAPTER 3

HYDRAULIC DESIGN OF SEWERS

3-1. Quantity of wastewater. For any segment of proposed sewer, the design wastewater flow must be determined. Sanitary or domestic wastes based on the population served by a given segment, extraneous infiltration/inflow, and contributing industrial flows must be added to produce the design flow. Where existing flow records or data showing required flow capacity are not available, the following criteria will be used to develop design flows.

a. Tributary area. This is the area contributing wastewater to a particular sewer segment. The quantity of wastewater which is collected by a particular segment is dependent upon the types of personnel and industrial activities which are regularly found in the area.

b. Sanitary or domestic wastes.

(1) Contributing population. Domestic wastewater quantities normally are to be computed on a contributing population basis, except as noted in paragraphs d. and e. which follow. The population to be used in design depends upon the type of area which the sewer serves. If the area is strictly residential, the design population is based on full occupancy of all housing and quarters served. If the area served is entirely industrial, the design population is the greatest number, employed in the area at any time, even though some of these persons may also be included in the design of sewers in the residential area. For sewers serving both residential and industrial areas, the design population includes residents and nonresidents, but no person should be counted more than once. For design purposes, one-third of the nonresident population will be added to the resident population.

(2) Average daily flow. The average daily flow will be computed by multiplying the resident and nonresident contributing populations by 100 gallons per capita per day plus admissible daily flows from commercial and industrial operations. The average daily flow will be used only for designing sewers to serve the entire installation, or large sections of the installation, and where a major portion of the wastewater is generated by residents over a 24-hour period.

(3) Average hourly flowrate. When designing sewers to serve small areas of the installation where several buildings or a group of buildings are under consideration, and where the majority of wastewater is generated by nonresidents or other short term occupants, the average hourly flowrate will be used. The average hourly flowrate will be computed based on the actual period of waste generation. For example, 1,000 nonresidents at 30 gallons per capita per day would generate 30,000 gallons in 8 hours for an average hourly flowrate of 3,750 gph

(90,000 gpd). Note that the average daily flow would still be 30,000 gpd, or 30,000 gallons in 24 hours, but the sewer must be designed hydraulically to carry the 30,000 gallons in 8 hours, not 24 hours.

(4) Extreme peak flowrate. Extreme peak rates of flow occur occasionally and must be considered. Sewers will be designed with adequate capacity to handle these extreme peak flowrates. Ratios of extreme peak flowrates at average flows will be calculated with the use of the following equation:

$$r = \frac{C}{Q^{0.167}}$$

where:

r = ratio of extreme peak flowrate to average flow
Q = average daily flow or average hourly flowrate in mgd, gpd, or gph
C = constant, 3.8 for mgd, 38.2 for gpd, or 22.5 for gph

When designing sewers to serve the entire installation, or large areas of the installation, and where a major portion of the wastewater is generated by residents over a 24-hour period, the average daily flow will be used in the formula, and the extreme peak flowrate will be computed by multiplying the average daily flow by the ratio r. However, for sewers serving small areas of the installation where several buildings or a group of buildings are being considered, and where the majority of wastewater is generated by nonresidents or other short term occupants, the average hourly flowrate will be used in the formula, and the extreme peak flowrate will be computed by multiplying the average hourly flowrate by the ratio r.

(5) Peak diurnal flowrate. The peak diurnal flowrate will be taken as one half of the extreme peak flowrate.

c. Infiltration. Extraneous flows from ground water infiltration will enter the sewer system and is to be accounted for by adding 500 to 1,000 gpd/per inch per mile of pipe, to the peak rate of flow. Tests required for newly constructed sewers normally limit leakage to 500 gpd/per inch per mile.

d. Industrial waste flows. Industrial waste quantities cannot be computed totally on a population or fixture unit basis. Industrial waste sewers and sanitary sewers will be designed for the peak industrial flow as determined for the particular industrial process or activity involved.

e. Fixture unit flow. The size of building connections, including those from theaters, cafeterias, clubs, quarters, and other such buildings, will in all cases be large enough to discharge the flow computed on a fixture unit basis. This requirement applies to building connections only, and not to the lateral or other sewers to which they connect.

3-2. Gravity sewer design. Sewers will be designed to discharge the wastewater flows as required by paragraph 3-1. Generally, it is not desirable to design sewers for full flow, even at peak rates. Trunk and interceptor sewers will be designed to flow at depths not exceeding 90 percent of full depth; laterals and main sewers, 80 percent; and building connections, 70 percent. The minimum sizes to be used are 6-inch for building connections and 8-inch for all other sewers. The following formula, charts, procedures, and criteria will be used for design.

a. Design formula and charts. The Manning formula will be used for design of gravity flow sewers as follows:

$$V = \frac{1.486}{n} R^{2/3} S^{1/2}$$

where:

V = velocity in fps
n = coefficient of pipe roughness
R = hydraulic radius in feet, and
S = slope of energy grade line in feet per foot

(1) Roughness coefficient. The design of life for the mobilization program is 5 years, and the sewer pipe can be considered new or relatively new during the entire design life of the installation. The roughness coefficient (n) for new pipe for use in the Manning formula will be 0.013 for pipe sizes 12 inches and larger, and 0.014 for pipe sizes 10 inches and smaller. Variation of n with depth of flow has been shown experimentally, and may be considered in designing sewers to flow partially full. Solutions to the Manning formula for full pipe flow is shown in figure 3-1, which will be used in conjunction with figure 3-2 for sewers flowing partially full.

(2) Velocity. Sewers will be designed to provide a minimum velocity of 2.0 fps at the average daily flow, or average hourly flowrate, and a minimum velocity of 2.5 to 3.5 fps at the peak diurnal flowrate, as determined in paragraph 3-1. Maximum velocity is set at 10.0 fps in the event that grit becomes a problem.

(3) Slope. Assuming uniform flow, the value of S in the Manning formula is equivalent to the sewer invert slope. Pipe slopes must be sufficient to provide the required minimum velocities and depths of cover on the pipe.

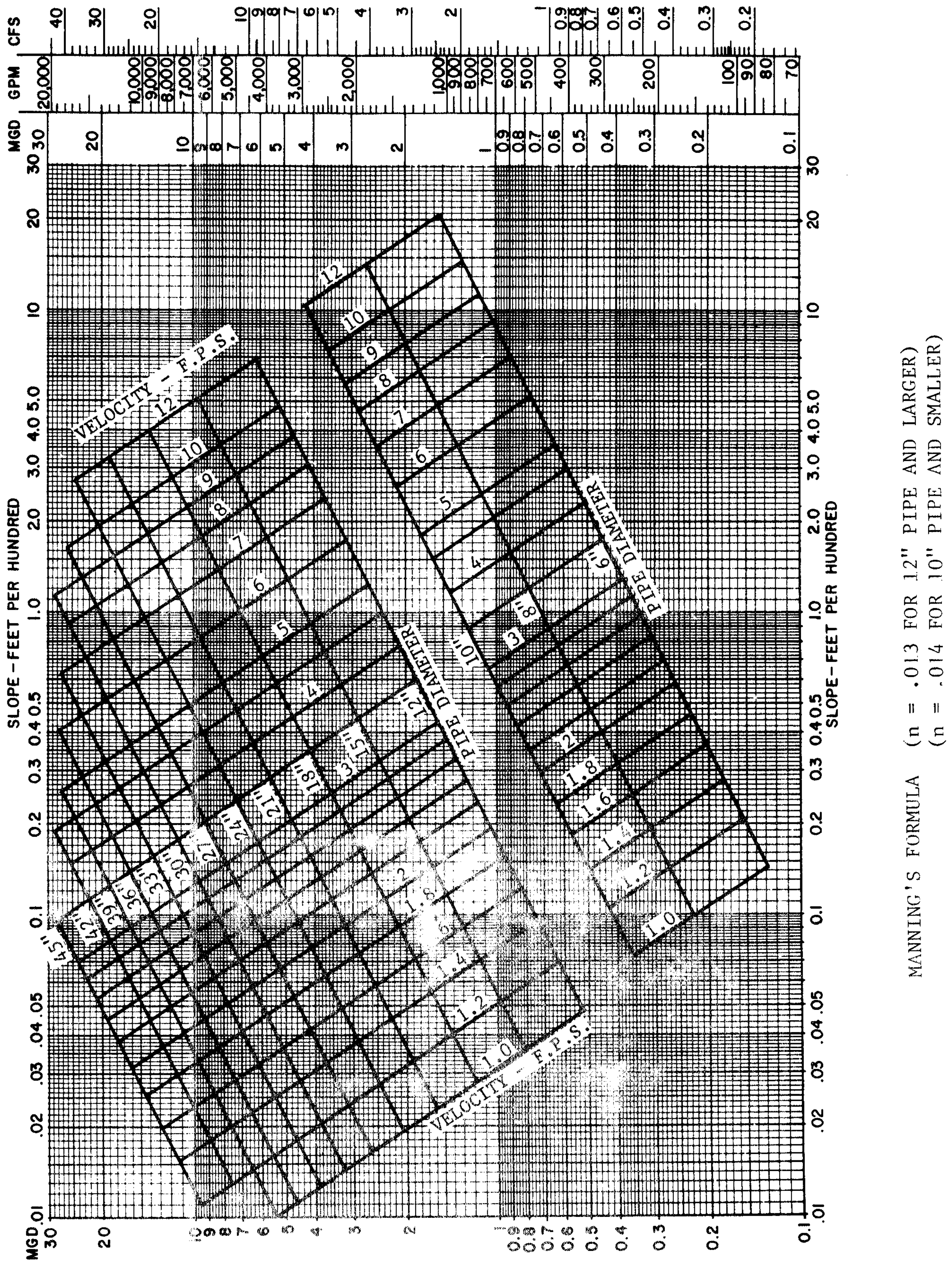

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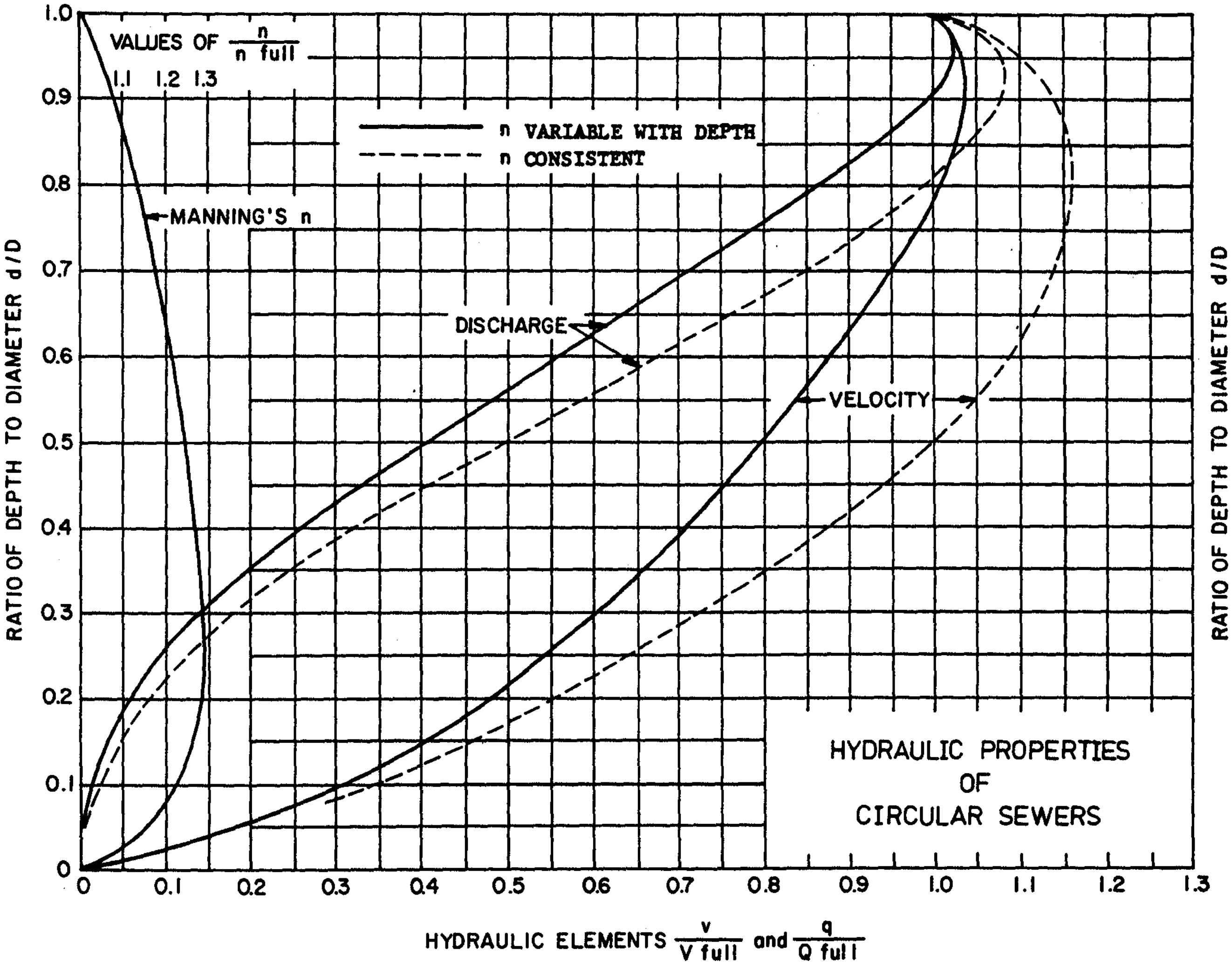
FIGURE 3-1. PIPE FLOW CHART



CLAY PIPE ENGINEERING MANUAL BY NATIONAL CLAY
PIPE INSTITUTE, 1982, P. 25.

FIGURE 3-2. HYDRAULIC PROPERTIES OF CIRCULAR SEWERS

(a) Adequate cover must be provided for frost protection. Generally, a minimum 2 feet of earth will be required to protect the sewer against freezing. Where frost penetrates to a considerably greater depth or lasts for an appreciable length of time, greater cover will be required.

(b) Sufficient cover must also be provided to protect the pipe against structural damage due to superimposed surface loadings. Concentrated and uniformly distributed loads are discussed in chapter 5.

b. Design procedure. After a preliminary layout has been made, a tabulation will be prepared setting forth the following information for each sewer section:

(1) Designation of manholes by numerals or letters.

(2) Contributing populations - resident and nonresident.

(3) Design flows - average, daily peak and extreme peak.

(4) Length of sewer.

(5) Invert elevations.

(6) Invert slope or gradient.

(7) Pipe diameter and roughness coefficient.

(8) Flow depths at design flows.

(9) Velocities at design flows.

(10) Depths of cover on the pipe - maximum and minimum.

c. Hydraulic profile. In most situations where small to medium sized gravity sewers are installed in long runs, it will be safe to assume uniform flow throughout the entire length of conduit. However, in cases where larger sewers, 24-inch diameter and above, are constructed in runs of less than 100 feet, and with a number of control sections where nonuniform flow may occur, a plot of the hydraulic profile is recommended.

d. Critical flow. Gravity sewers will ordinarily be designed to maintain subcritical flow conditions in the pipe throughout the normal range of design flows. However, there are exceptions in which supercritical flow may be required, and will be justified. Where supercritical flow will occur, care must be taken in the design to insure that downstream pipe conditions do not induce a hydraulic jump or other flow disturbance. Depths of flow within 10 to 15 percent of critical depth are likely to be unstable and will be avoided where pipes will flow from 50 to 90 percent full. Critical depths for various flows and pipe diameters can be obtained from standard hydraulics textbooks.